(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 February 2003 (13.02.2003)

PCT

(10) International Publication Number
WO 03/011523 A1

(51) International Patent Classification⁷: B24B 37/04, 57/02

(21) International Application Number: PCT/US02/24599

(22) International Filing Date: 2 August 2002 (02.08.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/921,588 2 August 2001 (02.08.2001) US
10/131,638 22 April 2002 (22.04.2002) US

(71) Applicant: APPLIED MATERIALS, INC. [US/US]; 3050 Bowers Avenue, Santa Clara, CA 95054 (US).

(72) Inventors: WITHERS, Bradley, S.; 1049 Galston Drive, Folsom, CA 95630 (US). MENG, Brenda, R.; 1123 Saddlewood Drive, San Jose, CA 95121 (US). VEREEN, Lidia; 4714 Lethram Court, Pleasanton, CA 94588 (US). SKARPELOS, Peter, N.; 1325 Sacramento Street, Berkeley, CA 94702-1235 (US). DOWNUM, Brian, J.; 11619 N.E. 15th Street, Vancouver, WA 98684 (US). WILLIAMS, Patrick; 363 Glenbriar Circle, Tracy, CA 95377 (US). KO, Terry, Kin Ting; 120 April Avenue, South San Francisco, CA 94080 (US). LEE, Christopher, Heung-Gyun; 1321 Webster Street #205, Alameda, CA 94501 (US). REYNOLDS, Kenneth, Reese; 115 Craig Way, Los Gatos, CA 95032 (US). HEARNE, John; 1456 Frontero Avenue, Los Altos, CA 94042 (US). HACHNOHI, Daniel; 630 Alger Drive, Palo Alto, CA 94306 (US).

(74) Agents: PATTERSON, Todd, B. et al.; Moser, Patterson & Sheridan, L.L.P., 3040 Post Oak Boulevard, Suite 1500, Houston, TX 77056 (US).

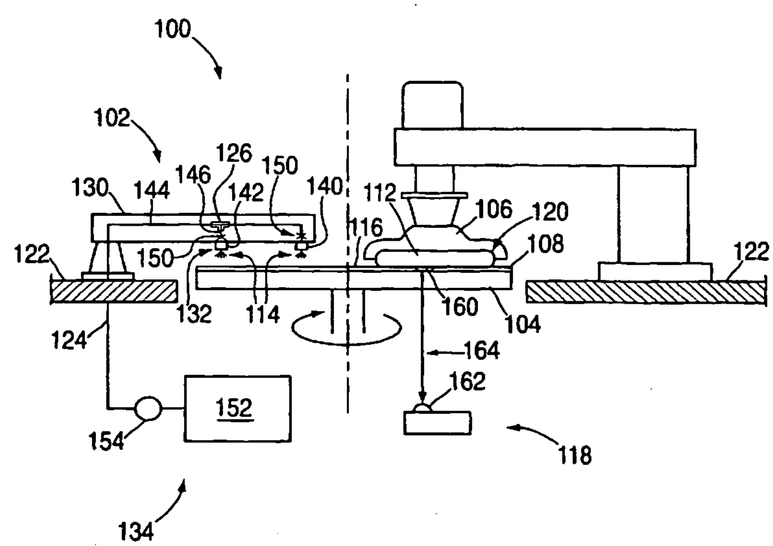
(81) Designated States (*national*): CN, JP, KR.

(84) Designated States (*regional*): European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR).

Published:
— *with international search report*

[Continued on next page]

(54) Title: MULTIPORT POLISHING FLUID DELIVERY SYSTEM



(57) Abstract: A method and system for delivering a polishing fluid to a chemical mechanical polishing surface (104) is provided. In one embodiment, the system includes an arm (104) having a delivery portion disposed at least partially over the polishing surface. A first nozzle and a second nozzle are disposed on the delivery portion of the arm. The first nozzle (132) is adapted to flow the polishing fluid at a first rate while the second nozzle is adapted to flow the polishing fluid at a second rate that is different than the first rate. A method for delivering a polishing fluid to a chemical mechanical polishing surface generally includes the steps of supplying the polishing fluid to a semiconductor polishing surface in one location at a first rate and providing the polishing fluid to the polishing surface at a second location at a second rate which is different than the first rate.

WO 03/011523 A1

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MULTIPORT POLISHING FLUID DELIVERY SYSTEM

Technical Field

Embodiments of the invention generally relate to a method and apparatus for polishing a substrate in a chemical mechanical polishing system.

Background Art

In semiconductor wafer processing, the use of chemical mechanical planarization, or CMP, has gained favor due to the enhanced ability to increase device density on a semiconductor workpiece, or substrate, such as a wafer. Chemical mechanical planarization systems generally utilize a polishing head to retain and press a substrate against a polishing surface of a polishing material while providing motion therebetween. Some planarization systems utilize a polishing head that is moveable over a stationary platen that supports the polishing material. Other systems utilize different configurations to provide relative motion between the polishing material and the substrate, for example, providing a rotating platen. A polishing fluid is typically disposed between the substrate and the polishing material during polishing to provide chemical activity that assists in the removal of material from the substrate. Some polishing fluids may also contain abrasives.

One of the challenges in developing robust polishing systems and processes is providing uniform material removal across the polished surface of the substrate. For example, as the substrate travels across the polishing surface, the edge of the substrate is often polished at a higher rate. This is due in part to the tendency of the substrate to "nose drive" due to frictional forces as the substrate moves across the polishing surface.

Another problem affecting polishing uniformity across the substrate's surface is the tendency of some materials to be removed faster than the surrounding materials. For example, copper is generally removed more rapidly than the material surrounding the copper material (typically an oxide) during polishing. The faster removal of copper, often referred to a dishing, is particularly evident when the width of the copper surface exceeds five microns.

Although many solutions have been utilized in order to mitigate the non-uniformity of the substrate as a result of polishing, none have proved to be

completely satisfactory. Thus, the demand for uniform, highly planarized surfaces is still a paramount concern due to the trend toward smaller decreased line sizes and increased device density.

Therefore, there is a need for improved polishing uniformity in chemical mechanical planarization systems.

Disclosure of Invention

In one aspect of the invention, a system for delivering a polishing fluid to a chemical mechanical polishing surface is provided. In one embodiment, the system includes an arm having a delivery portion disposed at least partially over the polishing surface. A first nozzle and a second nozzle are disposed on the delivery portion of the arm. The first nozzle is adapted to flow the polishing fluid at a first rate while the second nozzle is adapted to flow the polishing fluid at a second rate that is different than the first rate.

In another aspect of the invention, a method for delivering a polishing fluid to a chemical mechanical polishing surface is provided. In one embodiment, the method includes the steps of supplying polishing fluid to one location of a chemical mechanical polishing surface at a first rate and providing polishing fluid to a second location of the polishing surface at a second rate which is different than the first rate.

Brief Description of Drawings

So that the manner in which the above recited features of the present invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

Figure 1 is a simplified schematic of a polishing system having one embodiment of a polishing fluid delivery system;

Figure 2 is a plan view of the system of Figure 1;

Figure 3 depicts a simplified schematic of another polishing fluid delivery system;

Figure 4 is a comparison of polishing uniformity on substrates polished on conventional polishing system and the system of Figure 1;

Figure 5 is a top view of another embodiment of a polishing fluid delivery apparatus;

Figure 6 is a sectional view of the polishing fluid delivery apparatus of Figure 5 taken along section line 6--6;

Figure 7 is a partial top isometric view of one embodiment of a collet for retaining a polishing fluid delivery tube to the polishing fluid delivery apparatus;

Figure 8 is a partial sectional view of the polishing fluid delivery apparatus of Figure 5 taken along section line 8--8; and

Figure 9 is a cut-away isometric view of another embodiment of a polishing fluid delivery apparatus.

To facilitate understanding, identical reference numerals have been used, wherever possible, to designate identical elements that are common to the figures.

Best Mode for Carrying Out the Invention

Figure 1 depicts one embodiment of a polishing system 100 for polishing a substrate 112 having a polishing fluid delivery system 102 that controls the distribution of polishing fluid 114 across a polishing material 108. Examples of polishing systems which may be adapted to benefit from aspects of the invention are disclosed in United States Patent Application No. 09/144,456, filed February 4, 1999 by Birang, et al. and United States Patent No. 5,738,574, issued April 14, 1998 to Tolles, et al., both of which are hereby incorporated by reference in their entirety. Although the polishing fluid delivery system 102 is described in reference to the illustrative polishing system 100, the invention has utility in other polishing systems that process substrates in the presence of a polishing fluid.

Generally, the exemplary polishing system 100 includes a platen 104 and a polishing head 106. The platen 104 is generally positioned below the polishing head 106 that holds the substrate 112 during polishing. The platen 104 is generally disposed on a base 122 of the system 100 and coupled to a motor (not shown). The motor rotates the platen 104 to provide at least a portion of a relative polishing motion between the polishing material 108 disposed on the platen 104 and the

substrate 112. It is understood that relative motion between the substrate 112 and the polishing material 108 may be provided in other manners. For example, at least a portion of the relative motion between the substrate 112 and polishing material 108 may be provided by moving the polishing head 106 over a stationary platen 104, moving the polishing material linearly under the substrate 112, moving both the polishing material 108 and the polishing head 106 and the like.

The polishing material 108 is generally supported by the platen 104 so that a polishing surface 116 faces upward towards the polishing head 106. Typically, the polishing material 108 is fixed to the platen 104 by adhesives, vacuums, mechanical clamping or the like during processing. Optionally, and particularly in applications where the polishing material 108 is configured as a web, the polishing material 108 is releasably fixed to the platen 104, typically by use of a vacuum disposed between the polishing material 108 and platen 104 as described in the previously incorporated United States Patent Application No. 09/144,456.

The polishing material 108 may be a conventional or a fixed abrasive material. Conventional polishing material 108 is generally comprised of a foamed polymer and disposed on the platen 104 as a pad. In one embodiment, the conventional polishing material 108 is a foamed polyurethane. Such conventional polishing material 108 is available from Rodel Corporation, located in Newark, Delaware.

Fixed abrasive polishing material 108 is generally comprised of a plurality of abrasive particles suspended in a resin binder that is disposed in discrete elements on a backing sheet. Fixed abrasive polishing material 108 may be utilized in either pad or web form. As the abrasive particles are contained in the polishing material itself, systems utilizing fixed abrasive polishing materials generally utilize polishing fluids that do not contain abrasives. Examples of fix abrasive polishing material are disclosed in United States Patent No. 5,692,950, issued December 2, 1997 to Rutherford et al., and United States Patent No. 5,453,312, issued September 26, 1995 to Haas et al, both of which are hereby incorporated by reference in their entireties. Such fixed abrasive material 108 is additionally available from Minnesota Manufacturing and Mining Company (3M), located in Saint Paul, Minnesota.

The polishing head 106 generally is supported above the platen 104. The polishing head 106 retains the substrate 112 in a recess 120 that faces the polishing surface 116. The polishing head 106 typically moves toward the platen 104 and presses the substrate 112 against the polishing material 108 during processing. The polishing head 106 may be stationary or rotate, isolate, move orbitally, linearly or a combination of motions while pressing the substrate 112 against the polishing material 108. One example of a polishing head 106 that may be adapted to benefit from the invention is described in United States Patent No. 6,183,354 B1, issued February 6, 2001 to Zuniga et al., and is hereby incorporated by reference in its entirety. Another example of a polishing head 106 that may be adapted to benefit from the invention is a TITAN HEAD™ wafer carrier, available from Applied Materials, Inc., of Santa Clara, California.

The polishing fluid delivery system 102 generally comprises a delivery arm 130, a plurality of nozzles 132 disposed on the arm 130 and at least one polishing fluid source 134. The delivery arm 130 is configured to control the distribution of polishing fluid 114 on the polishing surface 116 of the polishing material 108. In one embodiment, the delivery arm 130 is configured to meter polishing fluid 114 at different flow rates along the arm 130. As the polishing fluid 114 is generally supplied from a single source, the polishing fluid 114 is disposed on the polishing material 108 in a uniform concentration but in varying amounts along the width (or diameter) of the polishing material 108.

The delivery arm 130 is generally coupled to the base 122 proximate the platen 104. The delivery arm 130 generally has at least a portion 136 that is suspended over the polishing material 108. The delivery arm 130 may be coupled to other portions of the system 100 as long as the portion 136 is positionable to deliver polishing fluid 114 to the polishing surface 116.

The plurality of nozzles 132 are disposed along the portion 136 of the delivery arm 130 which is disposed above the platen 104. In one embodiment, the nozzles 132 comprise at least a first nozzle 140 and a second nozzle 142. Typically, the first nozzle 140 is positioned on the arm 130 radially inward of the second nozzle 142 relative to the center of rotation of the polishing material 108. The distribution of

polishing fluid 114 across the polishing material 108 is controlled by flowing polishing fluid 114 from the first nozzle 140 at a rate different than the flow from the second nozzle 142.

As depicted in Figure 2, the first nozzle 140 generally flows polishing fluid 114 at a first rate to a first portion 202 of the polishing surface 116 while the second nozzle 142 flows polishing fluid 114 at a second rate to a second portion 104 of the polishing surface 116. In this manner, the distribution of polishing fluid 114 across the width of the polishing material 108 is regulated.

Returning to Figure 1, the flow rates exiting the first and second nozzles 140, 142 are generally different from one another. The flow rates may be fixed relative to each other or controllable. In one embodiment, the fluid delivery arm 130 includes a polishing fluid supply line 124 that is teed between the first and second nozzles 140, 142. A tee fitting 126 is coupled to the supply line 124 and has a first delivery line 144 and a second delivery line 146 branching therefrom that are coupled respectively to the nozzles 140, 142.

At least one of the nozzles 132 contains a flow control mechanism 150. The flow control mechanism 150 may be a device which provides a fixed ratio of flow between the nozzles 140, 142 or the flow control mechanism 150 may be adjustable to provide dynamic control of the flow rates. Examples of flow control mechanisms 150 include fixed orifices, pinch valves, proportional valves, restrictors, needle valves, restrictors, metering pumps, mass flow controllers and the like. Alternatively, the flow control mechanism 150 may be provided by a difference in the relative pressure drop between the fluid delivery lines 144, 146 coupling each nozzle 140, 142 and the tee fitting 126.

The polishing fluid source 134 is typically disposed externally to the system 100. In one embodiment, the polishing fluid source 134 generally includes a reservoir 152 and a pump 154. The pump 154 generally pumps the polishing fluid 114 from the reservoir 152 through the supply line 124 to the nozzles 132.

The polishing fluid 114 contained in the reservoir 152 is typically de-ionized water having chemical additives that provide chemical activity that assists in the removal of material from the surface of the substrate 112 being polished. As the

polishing fluid 114 is supplied to the nozzles 132 from a single source (*i.e.,* the reservoir 152), the fluid 114 flowing from the nozzles 132 is substantially homogeneous, *i.e.,* not varied in concentration of chemical reagents or entrained abrasives. Optionally, the polishing fluid may include abrasives to assist in the mechanical removal of material from the surface of the substrate. The polishing fluids are generally available from a number of commercial sources such as Cabot Corporation of Aurora, Illinois, Rodel Inc., of Newark, Delaware, Hitachi Chemical Company, of Japan, Dupont Corporation of Wilmington, Delaware among others.

In operation, the substrate 112 is positioned in polishing head 106 and brought in contact with the polishing material 108 supported by the rotating platen 104. The polishing head 106 may hold the substrate stationary, or may rotate or otherwise move the substrate to augment the relative motion between the polishing material 108 and substrate 112. The polishing fluid delivery system 102 flows the polishing fluid 114 through the supply line 124 to the first and second polishing nozzles 140, 142.

Figure 2 depicts a plan view of the system 100 illustrating the flow of polishing fluid 114 onto the portions 202 and 204 of the polishing material 108. A first flow 206 of polishing fluid 114 flows out the first nozzle 140 and onto the first portion 202 at a first rate while a second flow 208 of polishing fluid 114 flows out the second nozzle 142 and onto the second portion 204 at a second rate. Generally, the first flow 206 is different than the second flow 208 thus providing a controlled distribution of polishing fluid 114 across the polishing surface 116 of the polishing material 108. In one embodiment, the first flow 206 has a rate that is at least about 1.15 times a rate of the second flow 208. The controlled distribution of the polishing fluid 114 across the polishing material 108 allows material removal from the surface of the substrate 112 to be tailored across the width of the substrate 112 by controlling the relative flows of polishing fluid 114 onto the polishing material 108. Referring to Figure 2 for example, more polishing fluid 114 may be provided to the first portion 202 of the polishing material 108 than the second portion 204 (or vice versa). Optionally, additional nozzles may be utilized to provide different amounts of polishing fluid 114

on other portions of the polishing material 108 where at least two portions of the polishing material 108 have polishing fluid 114 disposed thereon at different flow rates.

In one mode of operation for example, the substrate 112 being polished by the system 100 is processed with polishing fluid 114 provided from the first nozzle 140 and the second nozzle 142. Polishing fluid 114 is disposed on the polishing material 108 from the first nozzle 140 at a first rate. Polishing fluid 114 is simultaneously disposed on the polishing material 108 from the second nozzle 142 at a second rate. In one embodiment, the first flow is about 1.2 to about 20.0 times second flow rate. The resulting polishing uniformity 402 from the process utilizing the polishing fluid delivery system 102 is depicted in Figure 4. Uniformity 404 of a conventional substrate polish achieved utilizing a conventional polishing fluid delivery system (*i.e.*, systems where polishing fluid is delivered to the polishing material solely from a single nozzle or tube) having the same total polishing fluid flow is provided for comparison. As illustrated in Figure 4, the uniformity 402 is improved over conventional results 404.

In configurations having dynamic (*i.e.*, adjustable) control mechanisms 150 such as proportional valves, needle valves, mass flow controllers, metering pumps, peristaltic pumps and the like, the distribution of polishing fluid 114 on the polishing material 108 may be tailored during the process. For example, the rate of polishing fluid from the first nozzle 140 may be applied to the polishing material 108 at a first rate during one portion of the process and adjusted to a second rate during another portion of the process. The rate of polishing fluid 114 delivery from the second nozzle 142 may also be varied during the polishing process. It should be noted that the adjustments of polishing fluid flows from either nozzle 140, 142 are infinite. The use of additional nozzles disposed between the first nozzle 140 and the second nozzle 142 allows the uniformity profile to be further modified and locally shaped by providing more or less polishing fluid 114 at a nozzle disposed between the first nozzle140 and the second nozzle 142 (see discussion of Figure 3 below).

Optionally, a polishing fluid delivery system having dynamic control over the flow rates from the nozzles 140, 142 may include a metrology device 118 to provide

process feed-back for real-time adjustment of the polishing fluid distribution. Typically, the metrology device 118 detects a polishing metric such as time of polish, thickness of the surface film being polished on the substrate, surface topography or other substrate attribute.

In one embodiment, the polishing material 108 may include a window 160 that allows the metrology device 118 to view the surface of the substrate 112 disposed against the polishing material 108. The metrology device 118 generally includes a sensor 162 that emits a beam 164 that passes through the window 160 to the substrate 112. A first portion of the beam 164 is reflected by the surface of the substrate 108 while a second portion of the beam 164 is reflected by a layer of material underlying the polished surface of the substrate 108. The reflected beams are received by the sensor 162 and a difference in wavelength between the two portions of reflected beams are resolved to determine the thickness of the material on the surface of the substrate 112. Generally, the thickness information is provided to a controller (not show) that adjusts the polishing fluid distribution on the polishing material 108 to produce a desired polishing result on the substrate's surface. One monitoring system that may be used to advantage is described in United States Patent Application Serial No. 08/689,930, filed August 16, 1996 by Birang et al., and is hereby incorporated herein by reference in its entirety.

Optionally, the metrology device 118 may include additional sensors to monitor polishing parameters across the width of the substrate 112. The additional sensors allow for the distribution of polishing fluid 114 to be adjusted across the width of the substrate 112 so that more or less material is removed in one portion relative another portion of the substrate 112. Additionally, the process of adjusting the flow rates from the nozzles 140, 142 may occur iteratively over the course of a polishing sequence to dynamically control the rate of material removal across the substrate 112 at any time. For example, the center of the substrate 112 may be polished faster by providing more polishing fluid to the center of the substrate 112 at the beginning of a polishing sequence while the perimeter of the substrate 112 may be polished faster at the end of the polishing sequence by providing more polishing fluid to the perimeter area.

Figure 3 depicts another embodiment of a polishing fluid delivery system 300 having a plurality of nozzles 302. The system 300 may be configured similarly to the fluid delivery system 102 of Figure 1 (*i.e.,* having a single polishing fluid delivery line) or may be configure so that each nozzle 302 has a dedicated supply line 304 coupled to a fluid source 306. Fluidly coupled to each supply line 304 is a metering device 308. The metering device 308 may be a metering pump such as a gear pump, a peristaltic pump, a positive displacement pump, a diaphragm pump and the like. Each metering device 308 is coupled to a controller (not shown) that controls the amount of polishing fluid 114 provided to each nozzle 302 of the system 300. As each metering device 308 is independently controllable, the flow of polishing fluid 114 from each of the plurality of nozzles 302 is controlled independent from the other nozzles so that the distribution of polishing fluid 114 on the polishing material 108 can be arranged in practically infinite configurations.

As described above, each metering device may vary the flow of polishing delivered to the polishing material 108 over the course of polishing. For example, one of the nozzles 302 may increase the flow of polishing fluid 114 flowing therethrough while the substrate is being polished. Another one of the nozzles may decrease the flow of polishing fluid 114 during polishing. Of course, infinite variations in nozzle flow rates at any time may be configured to produce a desired polishing result. As the flow of polishing fluid is independently controllable through each nozzle 302, polishing attributes may be tailored across the width of the substrate over the duration of substrate processing.

The fluid delivery source 306 may be used in concert with a metrology device 308 to control the rate or location of material removal from a surface 318 of the substrate 112 being polished. Generally, the rate of removal or remaining thickness of material disposed on the surface 318 of the substrate 112 may be detected by the metrology device 308 and provided to the controller which in turn, adjusts the various flow rates exiting each nozzle 302 to produce a desired polishing result, for example, faster polishing on the perimeter of the substrate 112.

In one embodiment, the polishing material 108 may include a window 310 that allows the metrology device 308 to view the surface 318 of the substrate 112

disposed against the polishing material 108. The metrology device 308 generally includes a sensor 314 that emits a beam 316 that passes through the window 310 to the substrate 112. A first portion of the beam 316 is reflected by the surface 318 of the substrate 108 while a second portion of the beam 316 is reflected by a layer 320 of material underlying the polished surface 318 of the substrate 108. The reflected beam is received by the sensor 314 and a difference in wavelength between the two portions of reflected beam is resolved to determine the thickness of the material on the surface 318 of the substrate 112. Generally, the thickness information is provided to the controller that adjusts the polishing fluid distribution on the polishing material 108 to produce a desired polishing result on the substrate's surface 318.

Optionally, the metrology device 308 may include additional sensors to monitor polishing parameters across the width of the substrate 112. The additional sensors allow for the distribution of polishing fluid 114 to be adjusted across the width of the substrate 112 so that more or less material is removed in one portion relative another portion of the substrate 112. Additionally, the process of adjusting the flow rates from the nozzles 302 may occur iteratively over the course of a polishing sequence to dynamically control the rate of material removal across the substrate 112 at any time. For example, the center of the substrate 112 may be polished faster by providing more polishing fluid to the center of the substrate 112 at the beginning of a polishing sequence while the perimeter of the substrate 112 may be polished faster at the end of the polishing sequence by providing more polishing fluid to the perimeter area.

Figure 5 depicts another embodiment of a polishing fluid delivery system 500. The system 500 includes an arm 502 that is adapted to position a plurality of polishing fluid delivery tubes 506 over a polishing surface 570. The arm 502 is configured to selectively provide polishing fluid to different portions of the polishing surface 570, thereby controlling the distribution of polishing fluid, and consequently the polishing rate, across the width (or diameter) of the polishing surface 570. In one embodiment, the distribution of polishing fluid across the polishing surface 570 may be controlled by positioning the tubes 506 to flow polishing fluid to

predetermined locations. In another embodiment, the flow through the tubes 506 may be selectively turned on or off.

In the embodiment depicted in Figure 5, the arm 502 has a plurality of polishing fluid delivery tube receives, for example, holes 504 in which the tubes 506 are selectively positioned. Generally, the arm 502 has a greater number of holes 504 than tubes 506 thereby allowing the individual tubes 506 to be selectively positioned along the arm 502. As the position of the tubes 506 along the arm 502 dictate which portions of the polishing surface 570 receive polishing fluid during polishing, the choice of which holes 504 are used to position the tubes 506 controls the distribution of polishing fluid on the polishing surface 570, allowing the control of local polishing rates across the width of the substrate 574 (shown in phantom). It is contemplated that the position of the tubes 506 may be secured and adjusted along the arm 502 by other devices or methods, for example, clamps, sliders, straps and slots, among others.

The arm 502 includes a first lateral side 508 and an opposing second lateral side 510 typically orientated perpendicular to the polishing surface 570. A distal end 512 couples the sides 508, 510. The polishing fluid delivery tube receiving holes 504 are disposed at least along one of the sides 508, 510. The arm 502 may include a bend along its length to provide clearance for a polishing head 572 that retains a substrate 574 (shown in phantom) against the polishing surface 570 during processing.

In the embodiment depicted in Figure 5, the holes 504 are arranged in along the sides 508, 510 and end 512 of the arm 500. A first set 514 of holes 504 is disposed along the first side 508, a second set 516 of holes 504 are disposed along the second side 510, and a third set 518 of holes 504 are disposed along the end 512. The number and position of holes 508 may vary to allow positioning of the tubes 506 at predetermined intervals to provide a predetermined polishing uniformity while polishing. For example, the first set 514 may include nine (9) holes 504 spaced at half inch intervals, the second set 516 may include ten (10) holes 504 space at half inch intervals while the third set 518 may include two (2) holes 504. Thus, the positions of the tubes 506 along the arm 502 may be selected to flow

polishing fluid to discreet portions of the polishing surface thereby controlling the local polishing rates across the width of the substrate.

In the embodiment depicted in Figure 5, the tubes 506 may be positioned in a predetermine group of holes 504 to produce a desired polishing uniformity on a substrate 574. A first tube 506A is positioned in one of the first set 514 of holes 504 to flow polishing fluid to a first portion 562 of the polishing surface 570. A second tube 506B is positioned in another of the first set 514 of holes 504 to flow polishing fluid to a second portion 564 of the polishing surface 570. A third tube 506C is positioned in one of the second set 516 of holes 504 to flow polishing fluid to a third portion 566 of the polishing surface 570. A fourth tube 506D is positioned in one of the third set 518 of holes 504 to flow polishing fluid to a first portion 562 of the polishing surface 570. By moving any one of the tubes 506A-D to another hole 504, the distribution of polishing fluid on the polishing surface 570 will be altered and correspondingly change the rate of material removal across the diameter of the substrate 574. The position of the tubes 506A-D may be moved along the arm 502 to produce a desired polishing result while polishing a single substrate (*i.e.*, in-situ), to enhance system flexibility when polishing different materials, and to provide greater flexibility of process control for tuning a particular process to yield a defined polishing uniformity or polished profile of the substrate. For example, the tubes 506A-D may be re-positioned from a first group of holes 504 to a second group of holes 504 in response to a change in substrate surface characteristics, for example, a change from oxide to copper polishing, a change in surface profiles between incoming substrates or a change in feature width, among others.

Alternatively, the distribution of polishing fluid on the polishing surface 570 may be changed by sequentially flowing polishing fluid the tubes 506. For example, polishing fluid may be provided through tubes 506A-C during a first portion of a polishing process to polish the substrate 574 at a predetermined polishing rate profile across the diameter of the substrate (*i.e.*, the rate of polishing is different across the diameter of the substrate). At a second portion of a polishing process, the flow through the fourth tube 506D is provided to change the distribution of polishing fluid on the polishing surface 570 to change the polishing rate profile. The

flow through the tubes 506A-D may be turned on and off in various combinations to produce a corresponding polishing performance. The sequence of flow through the tubes 506A-D may be controlled in response to a sensed polishing metric as described above. Alternatively, the sequence of flow through the tubes 506A-D may be selected to yield uniform polishing of the substrate by compensating for changes in other process attributes or parameters that effect local polishing rates.

Referring to Figure 6, the arm 502 is generally supported by a post 602 that facilitates rotating the arm 502 over a polishing surface 570. The arm 502 is orientated perpendicular to the post 602 and, in one embodiment, is offset or bent along its length. The post 602 additionally provides a conduit for routing the tubes 506 to the arm 502.

Each hole 504 formed in the arm 502 typically includes an upper threaded portion 606 and lower portion 604. The lower portion 604 has a smaller diameter then a diameter of the upper portion 606, forming a step 608 within the hole 506. The lower portion 604 generally is configured to allow the tube 506 to pass snugly therethrough. The upper portion 606 includes a threaded section 612. Each tube 506 is retained in one of the holes 504 by a collet 610.

Referring additionally to Figure 5, the collet 610 has a generally tapered cylindrical form with a threaded exterior 502. The collet 610 tapers from a central ring 506 to a narrow end 504. The narrow end 504 of the collet 610 includes a plurality of slots 508 that define fingers 510 extending from the central ring 506. The ring 506 is configured to fit snugly over the tube 506. After the tube 506 is inserted into the hole 504 to the desired depth, the collet 610 is engaged with the threaded section 612 of the hole 504. The tapered shape of the collet 610 causes the fingers 510 to be urged inwards against the tube 506 as the collet 610 is threaded into the upper portion 606 of the hole 504, thereby clamping the tube 506 within the hole 504.

The collet 610 allows the tube 506 to extend below the arm 502 to a predetermined length. Thus, an outlet 614 of the tube 506 may be securely positioned proximate the polishing surface while the arm 502 is maintain at a greater distance from the polishing surface and away from contaminants and other debris

the may deposit on the arm 502 and later contaminate and/or damage a substrate during polishing. In one embodiment, the outlet 614 of the tube 506 extends at least one inch below the arm 502.

Figures 6 and 8 depicts one embodiment of a plug 620 utilized to prevent polishing fluid and other contaminants from entering holes 504 that are not occupied by any of the tubes 506. The plug 620 generally includes a cylindrical body 622 having a concentric post 624 extending from a first end 628 and a threaded hole 630 formed concentrically in a second end 632. The post 624 is configured to snugly fill the lower portion 604 of the hole 504 to prevent polishing fluid and other contaminants from entering holes 504. The post 624 typically extends flush with or protrudes slightly from an underside 644 of the arm 502 facing the polishing surface 570. A set screw 626 is threaded into the upper portion 606 of the hole 506 and urges the plug 620 against the step 608 to secure the plug 620 within the hole 504. The plug 620 may be removed from the hole 504 by removing the set screw 626 and inserting a threaded object (not shown) into the threaded hole 630 of the plug 620. The plug 620 may then be pulled out from the hole 504.

Referring back to Figure 6, the arm 500 may include an optional spray system 640. The spray system 640 generally includes a tube 642 coupled to an underside 644 of the arm 500. The tube 642 includes a plurality of nozzles 646 coupled to or formed in the tube 642 at spaced-apart intervals. The tube 642 is coupled to a cleaning fluid source 648 by a conduit 650 routed through the post 602. The cleaning fluid source 648 generally provides pressurized cleaning fluid, such as de-ionized water, to the polishing surface 570 through the nozzles 646 to dislodge contaminants or other debris from the polishing surface. One spray system that may be adapted to benefit from the invention is described in United States Patent No. 6,139,406, issued October 51, 2000 to Kennedy, which is hereby incorporated by reference in its entirety.

Figure 9 depicts a sectional view of another embodiment of a polishing fluid delivery apparatus 900. The apparatus 900 includes an arm 902 having a first lateral side 904, an opposing second lateral side 906 and an under side 908 disposed between the sides 904, 906 that faces a polishing surface 910. The sides

904, 906 generally define a length of the arm 902, a portion of which is adapted to extend over the polishing surface 910.

A manifold 912, coupled to a polishing fluid source (not shown), extends along the length of the arm 902. The manifold 912 may be coupled to the arm 902, disposed in the arm 902 or formed integrally with the arm 902. The manifold 912 generally includes a plurality of outlets 914 disposed in a spaced-apart relation along the length of the manifold 912. The outlets 914 are adapted to flow polishing fluid from the manifold 912 to discreet portions of the polishing surface 910.

Each outlet 914 includes a flow control mechanism 916 coupled thereto. The flow control mechanism 916 may be a manual or automated flow control device, such as pinch valves, proportional valves, needle valves, shut-off valves, metering pumps and mass flow controllers among others. The flow control mechanisms 916 allow the flow from each outlet 914 to be selectively turned on or off to control the distribution of polishing fluid across the width of the polishing surface 910, which correspondingly results in control of a polishing profile of a substrate polished on the surface 910.

In one embodiment, the flow control mechanism 914, for example, a solenoid valve, is coupled to a controller 918. The controller 918 allows each flow control mechanism 914 to be opened or closed in a predetermined sequence to facilitate tailoring the rate of material removal across the diameter of a substrate being polished. The use of a controller 918 allows the rate profile to be adjusted in-situ. For example, the controller 918 may be coupled to a metrology device 118 as described in Figure 1 to change the polishing profile in response to a polishing metric such as time of polish, thickness of the surface film being polished on the substrate, surface topography or other substrate attribute.

A spray system 920 may also be coupled to the arm 902 and adapted to spray cleaning fluid on the polishing surface 920. The spray system 920 is generally similar to the spray system 640 described with reference to Figure 6.

Therefore, the polishing fluid delivery system allows for the rate of material removal during polishing to be tailored across the width of the substrate by controlling the distribution of polishing fluid to various portions of a polishing surface.

The distribution of polishing fluid may be controlled by controlling the relative amount of polishing fluid delivered from different locations along the arm, by changing the positions of polishing fluid delivery tubes along an arm extending over the polishing surface, or by selectively turning on and off the flow from the tubes to polishing faster in one region of the substrate relative another. Although with creating a more flexible process window, controlling the distribution of the polishing fluid advantageously reduces the amount of polishing fluid consumed during polishing, thereby reducing processing costs.

Although the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise other varied embodiments that still incorporate the teachings and do not depart from the scope and spirit of the invention.

What is claimed is:

1. A system for delivering a polishing fluid to a chemical mechanical polishing surface comprising:

an arm having a delivery portion disposed at least partially over the polishing surface;

a first nozzle disposed on the delivery portion and adapted to flow the polishing fluid at a first rate; and

at least a second nozzle disposed on the delivery portion and adapted to flow the polishing fluid at a second rate that is different than the first rate.

2. The system of claim 1, wherein at least one of the first nozzle or the second nozzle further comprises a flow control device coupled thereto.

3. The system of claim 2, wherein the flow control device is a flow control selected from the group consisting of orifices, needle valves, proportional valves, pinch valves, restrictors, mass flow controllers and a metering pumps.

4. The system of claim 1, wherein the arm further comprises a polishing fluid delivery line coupled to both the first and second nozzle.

5. The system of claim 1 further comprising a first fluid source coupled to the first nozzle and a second fluid source coupled to the second nozzle.

6. The system of claim 1 further comprising a plurality of nozzles adapted to flow polishing fluid at a controlled rate, wherein each nozzle is independently controllable.

7. The system of claim 1 further comprising a rotating platen adapted to support a polishing material, the polishing material comprising the polishing surface.

8. The system of claim 1, wherein the first nozzle is disposed radially inward of the second nozzle relative to the center of rotation of the polishing pad, and wherein the first flow is at least 1.15 time greater than the second flow.

9. The system of claim 1, wherein first flow is about 1.2 to about 20 times the second flow rate.

10. The system of claim 1 further comprising a metrology device adapted to provide information utilized to control at least one of the flows through the nozzles.

11. A system for delivering a polishing fluid to a chemical mechanical polishing surface comprising:

a platen supporting the polishing surface;

a polishing head disposed over the platen;

an arm having a delivery portion disposed at least partially over the polishing surface;

a first nozzle disposed on the delivery portion and adapted to flow the polishing fluid at a first controllable rate;

at least a second nozzle disposed on the delivery portion and adapted to flow the polishing fluid at a second controllable rate that is different than the first controllable rate; and

a metrology device adapted to provide information utilized to control at least one of the flows through the nozzles.

12. A system for delivering a polishing fluid to a chemical mechanical polishing surface, comprising:

an arm having an underside adapted to face the polishing surface and a plurality of tube receivers; and

at least one tube adapted to flow polishing fluid coupled to the arm and positionable between at least two of the tube receivers.

13. The system of claim 12, wherein at least two of the tube receivers define:

a first set of tube retaining holes that are spaced along a first side of the arm; and wherein at least two other tube receivers define:

a second set of tube retaining holes formed in the arm spaced equidistant a second side of the arm disposed opposite the first side.

14. The system of claim 12 further comprising:

a collet disposed in each tube receiver having a tube passing therethrough and coupling the tube to the arm.

15. The system of claim 12 further comprising:

at least one plug disposed in a hole not occupied by the tubes.

16. The system of claim 15, wherein the plug further comprises:

a central body; and

a post extending from the central body, the post disposed at least flush with or protruding beyond the arm, and wherein each hole further comprises:

a first portion having a threaded section;

a second portion disposed coaxially to the first portion and having a diameter smaller than a diameter of the first portion, the post of the plug filling the second portion;

a step defined at an interface between the first portion and the second portion; and

a set screw engaged with the threaded section and urging the central body of the plug against the step.

17. The system of claim 12 further comprising:

a means for selectively changing the combination of tubes through which polishing fluid flow.

18. A system for delivering a polishing fluid to a chemical mechanical polishing surface, comprising:

an arm;

a plurality of polishing fluid delivery tubes;

a plurality of holes formed in the arm for receiving the polishing fluid delivery tubes, each of the tubes disposed through one of the holes and coupled to the arm; and

wherein a relationship between the polishing fluid delivery tubes and holes is expressed by:

$A / B > 1$

where:

A is a number of holes; and

B is a number of polishing fluid delivery tubes.

19. A method of supplying a polishing fluid to a chemical mechanical polishing surface comprising:

flowing the polishing fluid onto the pad at a first location at a first rate; and

flowing the polishing fluid on the pad at a second location at a second rate that is different than the first rate.

20. The method of claim 19, wherein the first rate is independently controllable relative the second rate.

21. The method of claim 19, wherein the step of flowing the polishing fluid at a first rate further comprises:

adjusting the flow rate during polishing in response to a polishing metric.

22. A method for delivering a polishing fluid to a polishing surface of a chemical mechanical polisher, the method comprising:

providing a polishing fluid delivery arm having a plurality of tube retaining positions exceeding the number of polishing fluid delivery tubes coupled to the arm; and

selecting a relative spacing between at least a first and a second polishing fluid delivery tube along the arm from the plurality of tube retaining positions to produce a desired polishing result.

23. The method of claim 22, wherein at least one of the polishing fluid tubes is moved to a different position along the arm in response to a change in surface characteristics of the substrate being polished.

24. The method of claim 22, wherein at least one of the polishing fluid tubes is moved to a different position along the arm to change local polishing rates across a diameter of a substrate.

25. A method for delivering a polishing fluid to a polishing surface of a chemical mechanical polisher, the method comprising:

flowing polishing fluid into a manifold coupled to a plurality of outlets disposed in a spaced-apart relation over the polishing surface;

allowing flow of polishing fluid through at least one of the outlets; and

preventing flow of polishing fluid through at least one of the outlets, wherein at least one of the outlets having a condition characterized by flow or no flow of polishing fluid therethrough is changed to the opposite condition in situ.

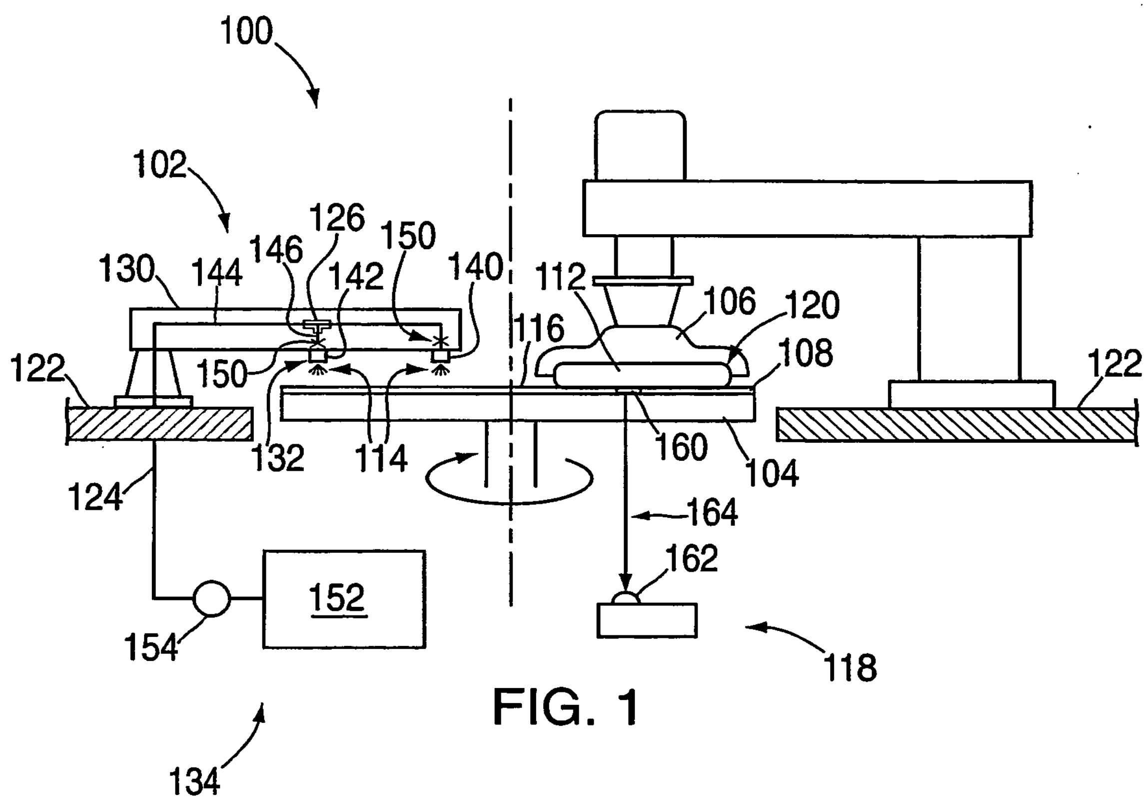
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FIG. 1

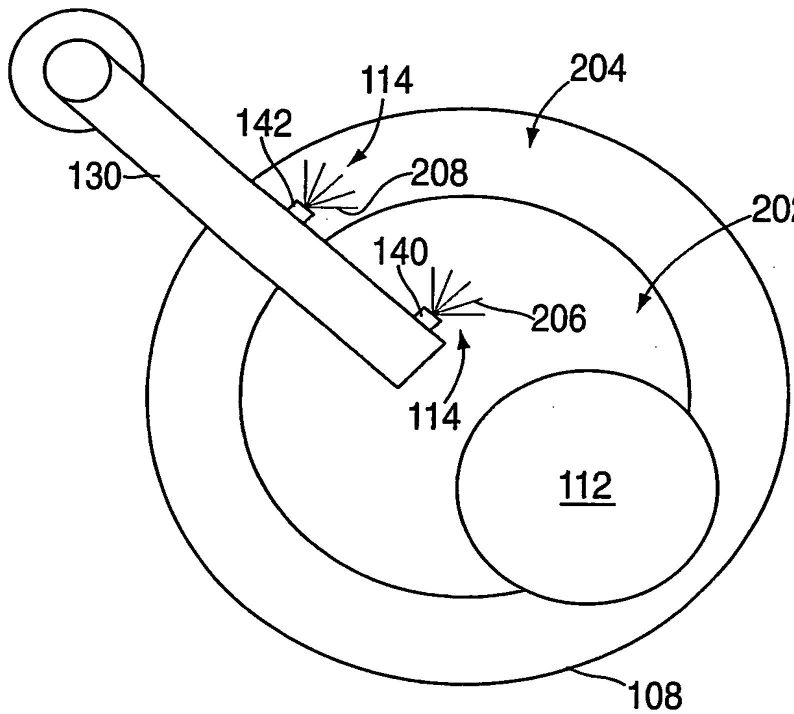


FIG. 2

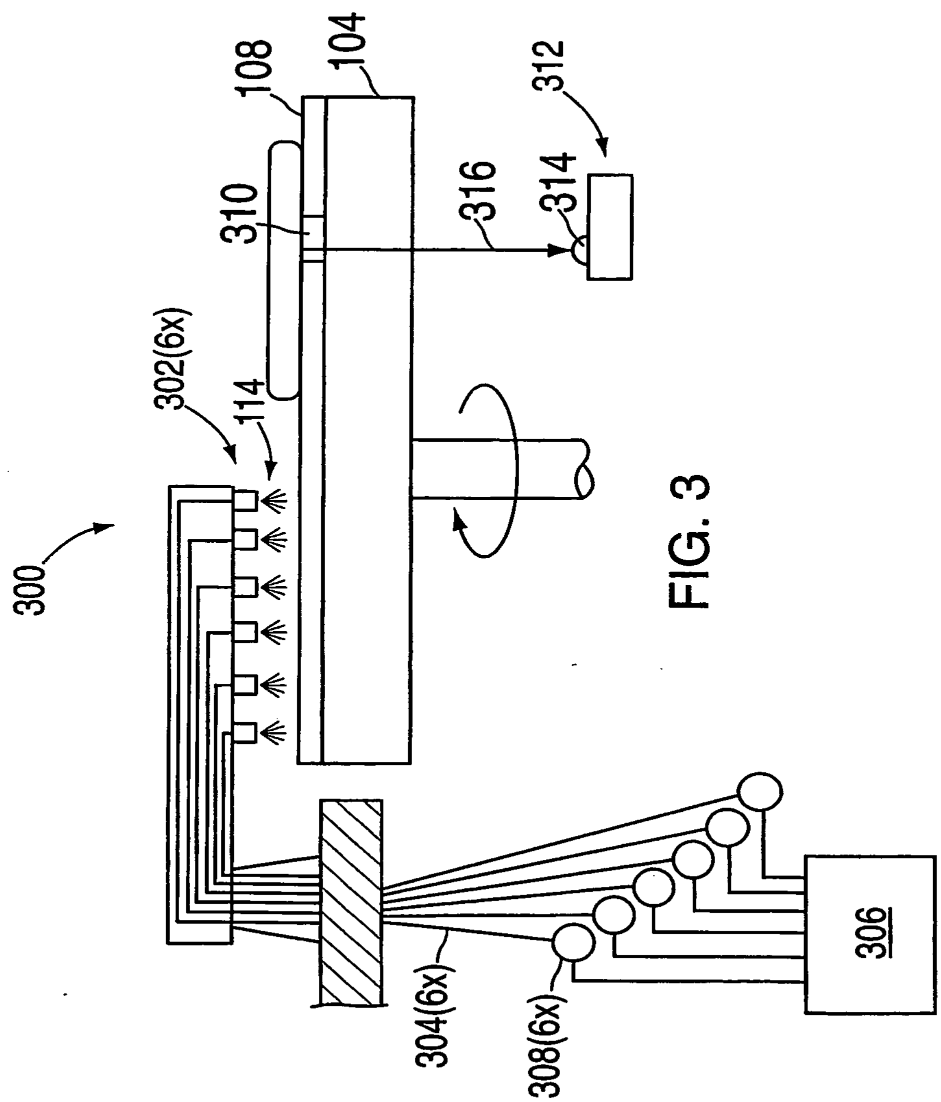
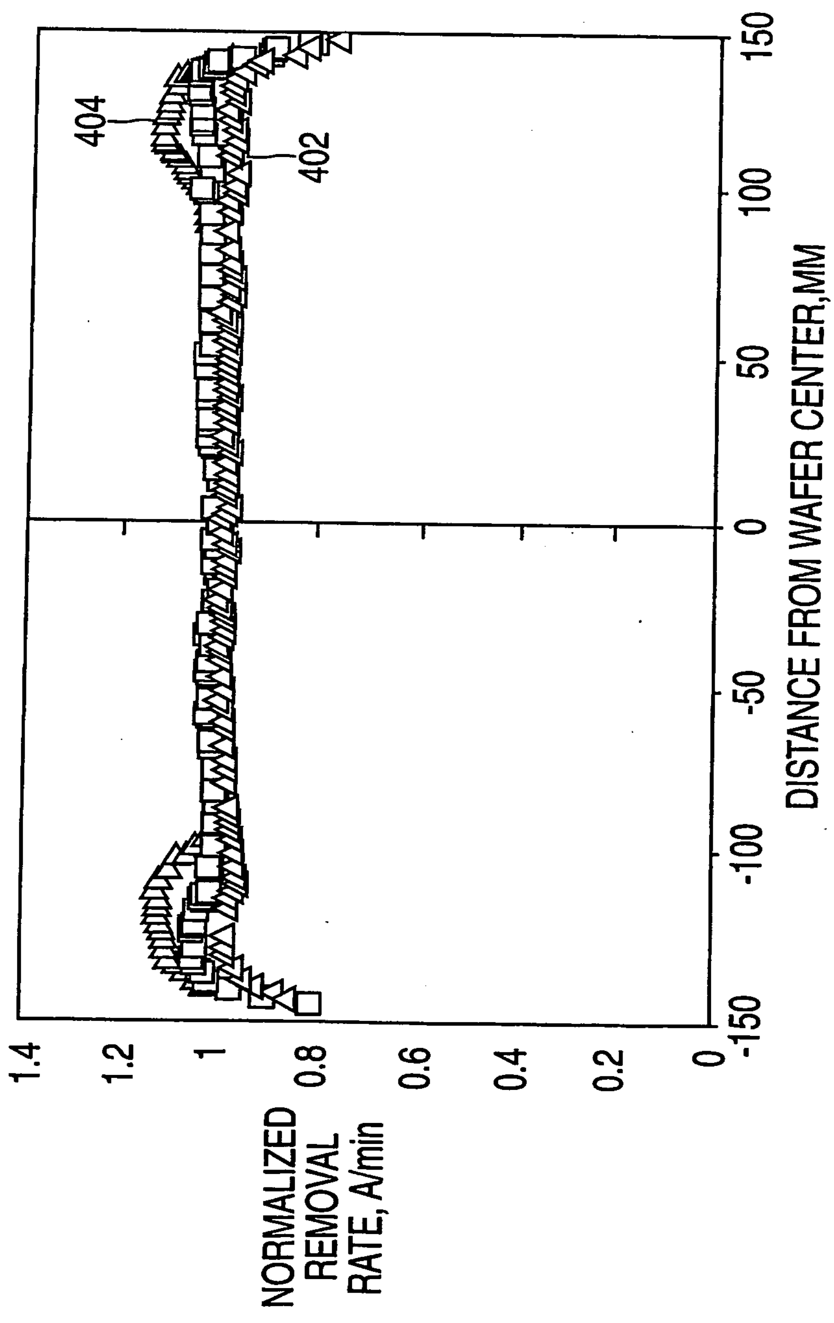


FIG. 3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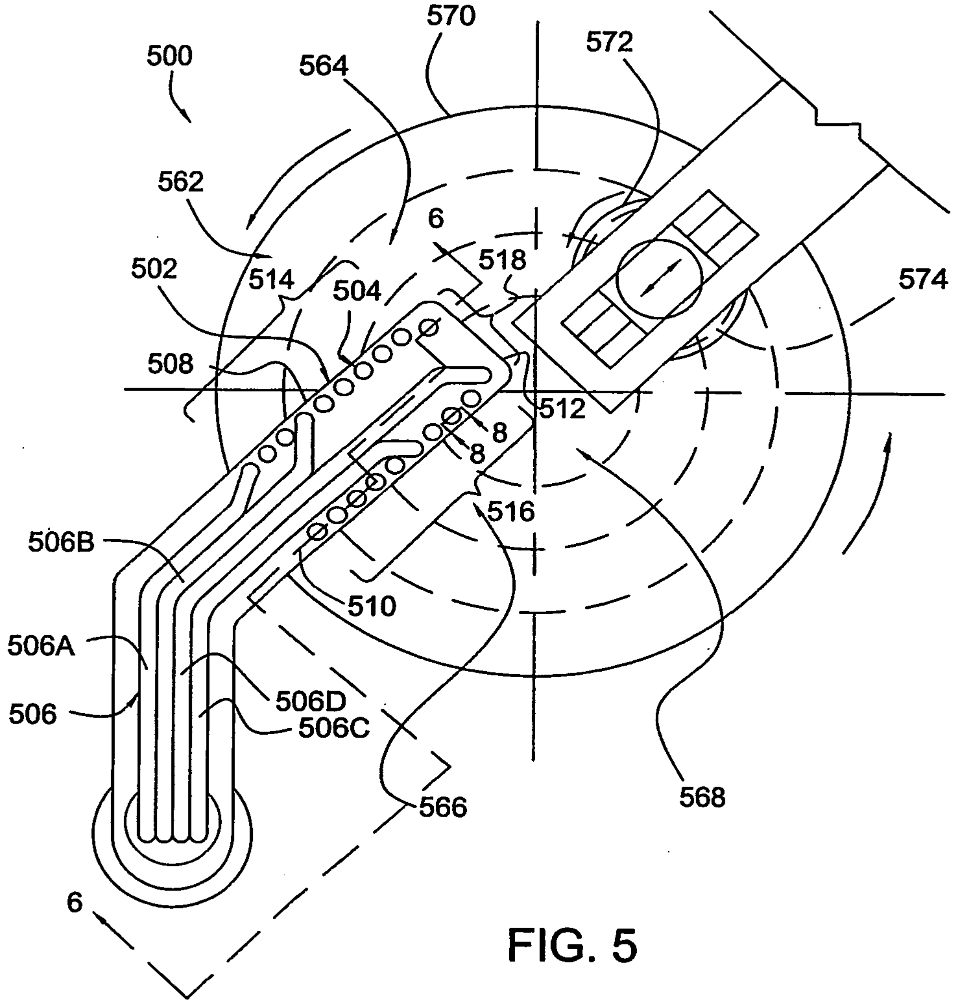
1.2
1
0.8
0.6
0.4
0.2
0
-150
-100
-50
0
50
100
150
DISTANCE FROM WAFER CENTER,MM
404
402

FIG. 4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572
564
562
6
518
574
502
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506B
510
506A
506D
506
506C
566
568
6

FIG. 5

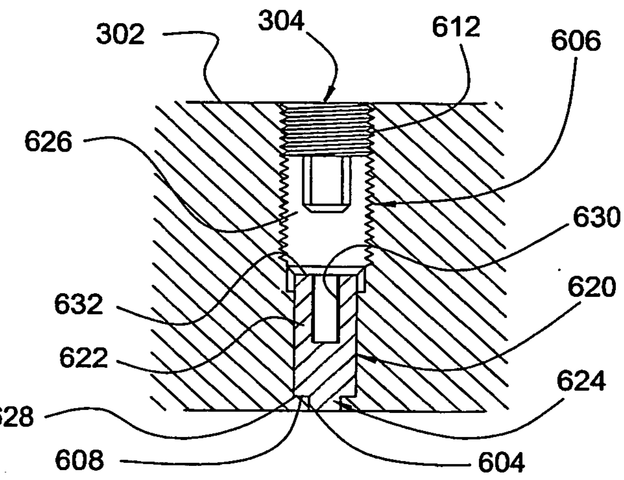

FIG. 8

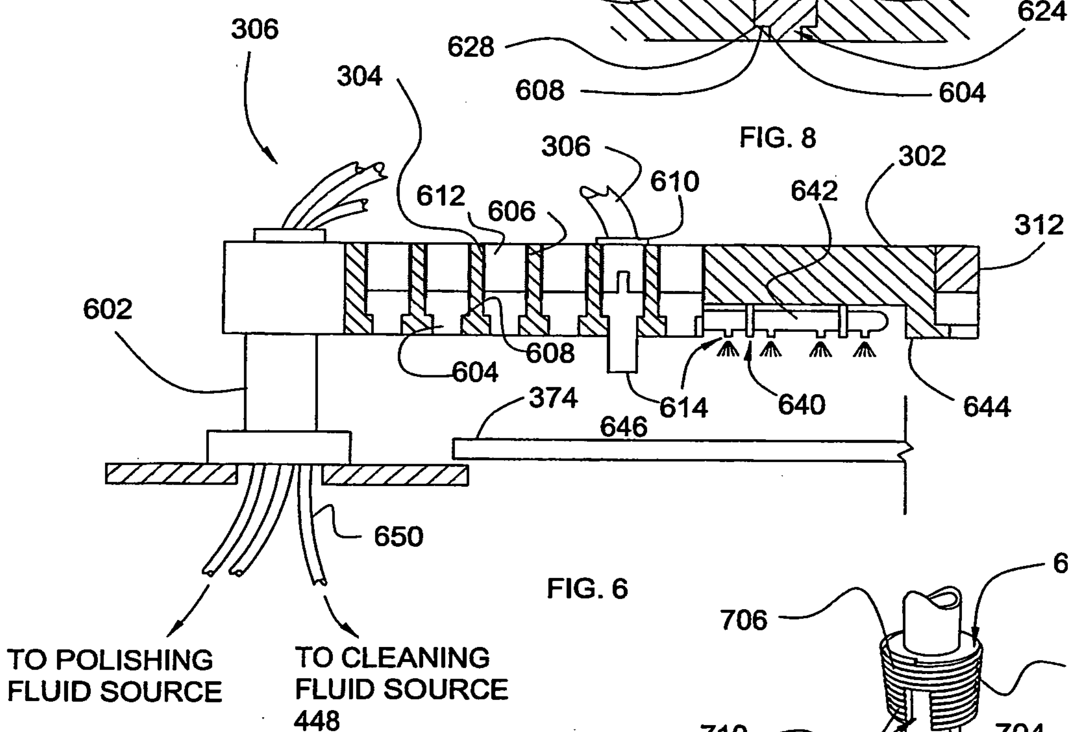

FIG. 6

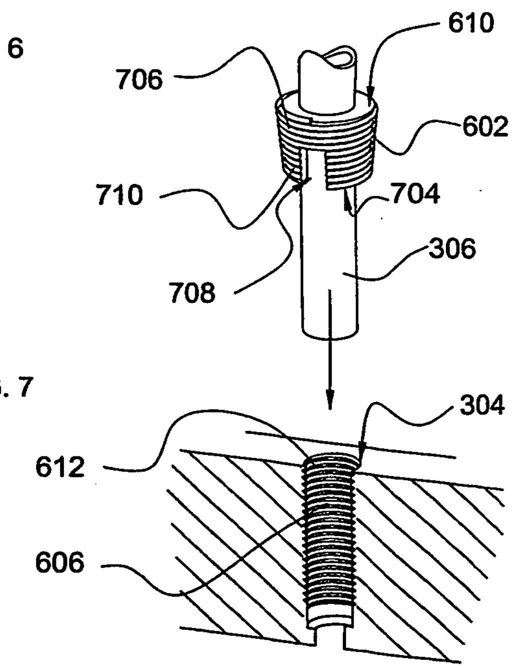

FIG. 7

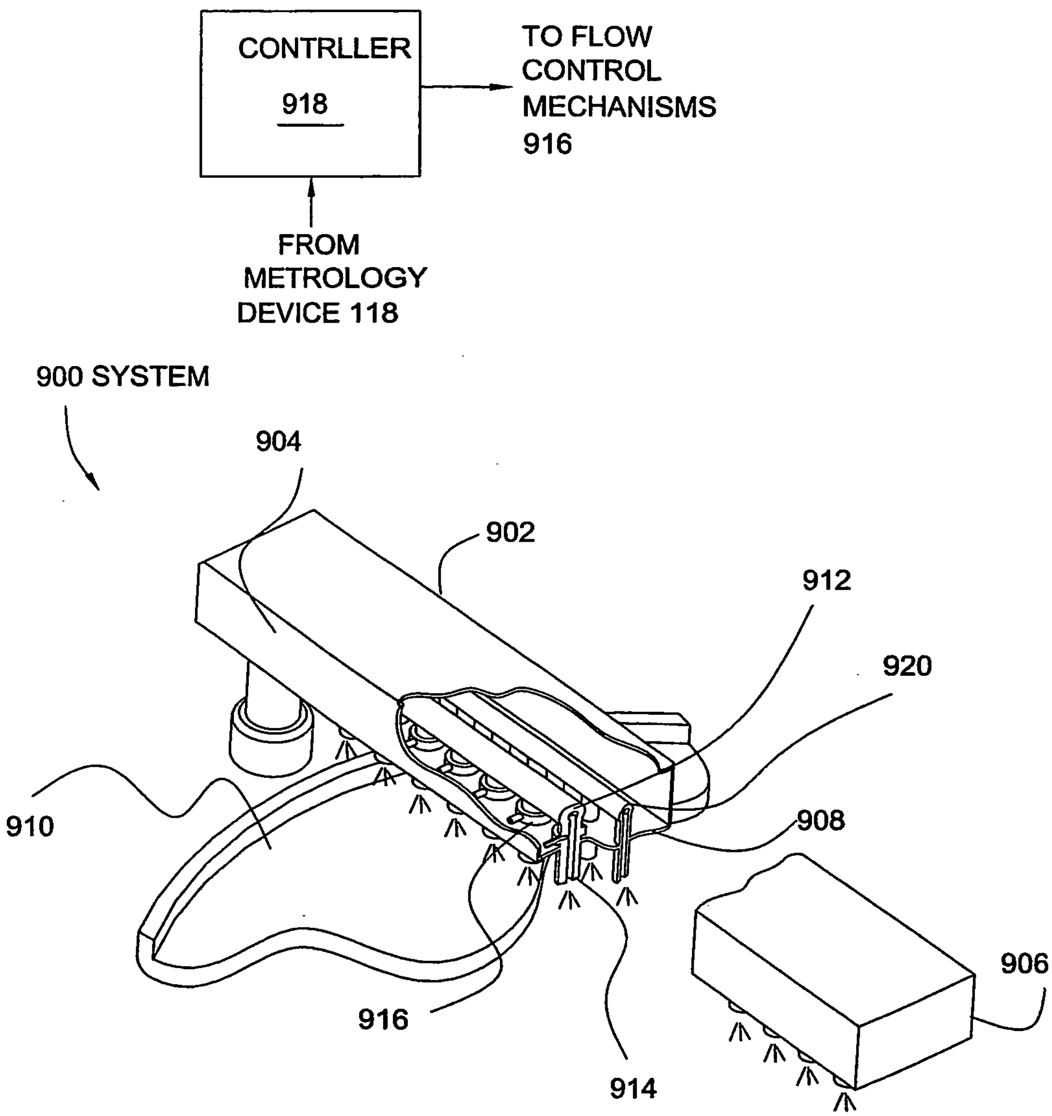
CONTRLLER
918
TO FLOW
CONTROL
MECHANISMS
916
FROM
METROLOGY
DEVICE 118
900 SYSTEM
904
902
912
920
910
908
906
916
914

FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/24599

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B24B37/04 B24B57/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B24B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 679 063 A (KIMURA ET AL.) 21 October 1997 (1997-10-21) column 5, line 8 - line 55; figures	1-25
A	EP 1 095 734 A (EBARA CORPORATION) 2 May 2001 (2001-05-02) column 6, line 11 - line 20; figures	1,11,12, 18,19, 22,25
A	US 5 716 264 A (KIMURA ET AL.) 10 February 1998 (1998-02-10) column 7, line 4 - line 13	1,11,12, 18,19, 22,25

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 October 2002	25/10/2002

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Int[illegible]onal Application No
PCT/US 02/24599

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 23, 10 February 2001 (2001-02-10) -& JP 2001 150345 A (APPLIED MATERIALS INC), 5 June 2001 (2001-06-05) abstract; figure 7 ---	1,11,12, 18,19, 22,25
A	US 6 149 508 A (VANDELL ET AL.) 21 November 2000 (2000-11-21) column 15, line 55 - line 63; figures -----	1,11,12, 18,19, 22,25

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

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Information on patent family members

International Application No
PCT/US 02/24599

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